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DISPERSAL OF SUPERCOOLED STRATUS CLOUDS BY SILVER IODIDE SEEDIN--ETC(U)

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During February 1977, a field program was conducted in northern Michigan to determine the feasibility of using silver iodide flares to make clearings in supercooled stratus decks over pre-selected ground locations. Targeting of the clearings was always possible if an accurate measurement of the wind at cloud height were available. The temperature in the upper portion of the cloud is apparently the critical meteorological parameter. On no occasion was a clearing effected when the cloud-top temperature was -6° C or warmer; however clearing did occur when cloud base temperature was as warm as -3°C.

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DISPERSAL OF SUPERCOOLED STRATUS CLOUDS BY SILVER IODIDE SEEDING

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1. INTRODUCTION

For over thirty years, beginning with its participation in the Wilmington Cloud Physics Project in 1947, the Air Force has had a continuing interest in the dispersal of supercooled stratus clouds by seeding from aircraft. Most Air Force field programs concentrated on dry ice as the seeding agent. Experiments by Downie and Silverman (1959) demonstrated the importance of seeding rate and the measurements necessary to position a clearing over a predetermined location. Later tests, by Vickers and Church (1966), correlated the effectiveness of the seeding with various meteorological parameters, the seeding rate, and the size of the dry ice pellets.

It is obvious when reviewing the results of these early tests that, because of the bulk of material needed, seeding had to be done from a large aircraft such as a C-130. Silver iodide, though less effective than dry ice at temperatures warmer than -6°C, could conceivably be injected into the cloud using a much simpler dispensing system which would permit seeding with a much smaller aircraft. Consequently, a field program was initiated to develop an efficient means of dispensing the silver iodide. Another objective of the tests was to demonstrate that consistent positioning of the clearings over a predetermined ground location can be achieved. It was also hoped that the limits of the technique, in terms of cloud thickness and temperature, could be determined.

2. THE FIELD PROGRAM

2.1 Location

Preceding the field tests, an exhaustive site selection study was made, based on climatology, accessibility, and availability of airspace in which to conduct the tests. The area chosen is shown in Figure 1. The airport at Traverse City, Michigan was selected as the base of operations. Two airfields, Roscommon Airport at Houghton Lake, approximately 50 miles to the southeast, and Kincheloe AFB, 120 miles northeast, were used as ground targets. It was estimated from climatology that conditions would be favorable for seeding 73 percent of the time.

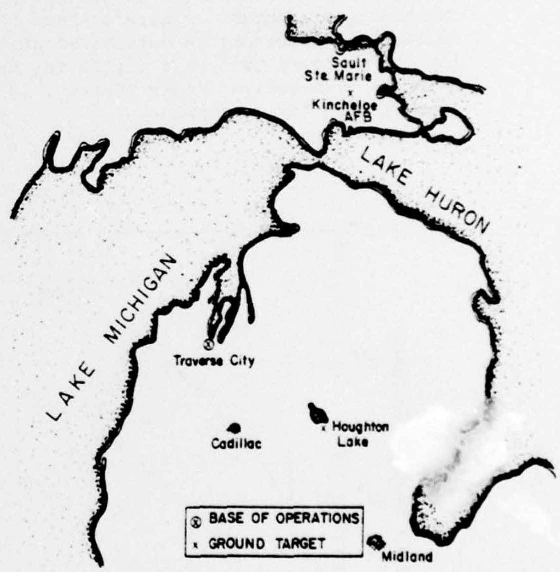

Figure 1. Site of Air Force supercooled stratus dispersal program, February/March, 1977.

2.2 Seeding Agent

Pyrotechnically generated silver iodide was selected as the seeding agent, primarily because of its superior logistic characteristics and flexibility of delivery. Ejectable flares, rather than the burn-in-place type, were chosen because: they provide essentially instantaneous dispersion in the vertical; they allow

the seeding rate to be easily adjusted by varying the firing interval; and they allow the aircraft to remain in clear air above the cloud top.

The tests reported here constitute the first field application of the flares for dispensing stratus clouds. These flares, developed by Nuclei Engineering, Incorporated (NEI), differ in two important aspects from the standard units used in previous weather modification programs. First, they are smaller in diameter -- 0.75 in. instead of the standard 1.375 in. Reduction of the diameter follows work by the Naval Weapons Center (NWC), China Lake, California, in their recent development of a seeding system for Project Stormfury.

In addition, the formula (TB-1, developed by NWC) has been modified by the addition of a small amount of chlorine. This formula was developed by NEI in support of the Florida Area Cumulus Experiment (FACE). Conceivably the chlorine replaces some of the iodine in the crystal lattice, creating preferred sites for nucleation because of the strain introduced.

The modified flares have been tested at the Cloud Simulation and Aerosol Laboratory, Colorado State University, before their use in the Michigan program. Figure 2 shows the nucleation efficiency as determined at CSU. Data for the standard TB-1 unit (1.375 in. diameter, undoped) from earlier tests (Garvey, 1975) are also plotted for comparison.

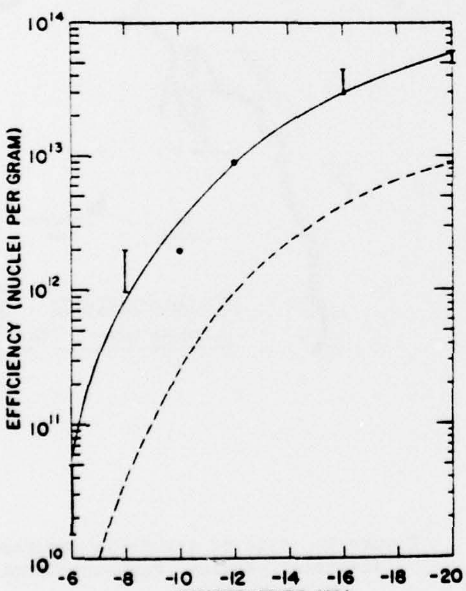

Figure 2. Nucleation efficiency of AgI flares. Solid line is best fit to the data for chlorine-doped, 0.75 in. flares. Dashed line is for large diameter (1.375 in), untreated flares.

2.3 Seeding Rates

A theoretical estimate of the seeding rate for silver iodide to disperse a stratus deck of a given temperature and thickness can be made by extrapolation from previous experience with dry ice. Vickers and Church found that for cloud decks approximately 1000 feet thick, a minimum seeding rate of 2 lbs/n. mi. was required. Fukuta et al (1971) have determined that the number of ice crystals generated per gram of dry ice is 8×10^{11}, over a wide range of temperatures and pellet sizes. This would indicate that approximately 7.3×10^{14} nuclei/n. mi./1000 feet thickness would have to be generated for effective dispersal. Referring to Figure 2, this would correspond, at -10°C, to a seeding rate of approximately 360 gm AgI/n. mi./ 1000 ft.

Seeding rates were determined during the field tests, first by using the critical value of 7.3×10^{14} nuclei and the efficiency curve of Figure 2, later adjusting the result in accordance with the outcome of the tests. The flares that were used in the test program contained either 10, 20 or 30 gms of silver iodide. The 10 gm flares burn over a fall distance of 2000 ft, 20 gms over 4000 ft, and 30 gms over 6000 ft. The depth of the clouds dictated the flare size.

2.4 Procedure

Two aircraft participated in the field tests. Seeding was done from a modified Piper Aztec. The cartridges containing the silver iodide flares were carried in a rack mounted on the belly of the aircraft. An on-board Hewlett-Packard 9815 programmable calculator controlled the firing sequence.

Direction of the tests and photographing of the results were done from a Cessna Turbo-210, which operated at an altitude approximately 5000 feet above the cloud top.

Prior to seeding, measurements were made of the temperature and altitude of cloud base and cloud top, the wind speed and direction at cloud top, and the turbulence intensity within the cloud. These were used to determine the flare size, seeding rate, and appropriate location of the seeding area.

Two types of patterns were used. In the line test, seeding was done in a straight line, one to two nautical miles long, with variable seeding rates that spanned an order of magnitude (for example, from 10 to 100 gm/n. mi./ 1000 ft. cloud thickness). The primary purpose of the line tests was to determine the optimum seeding rate. The raster test (Figure 3) consisted of a series of equal length parallel lines, between one and three n. mi. long, spaced between 0.5 and 1.5 n. mi. apart. The seeding rate, which was based on the results of a line test done roughly one hour before, was kept constant. The primary purpose of the raster tests was to position the clearing over a predetermined ground location.

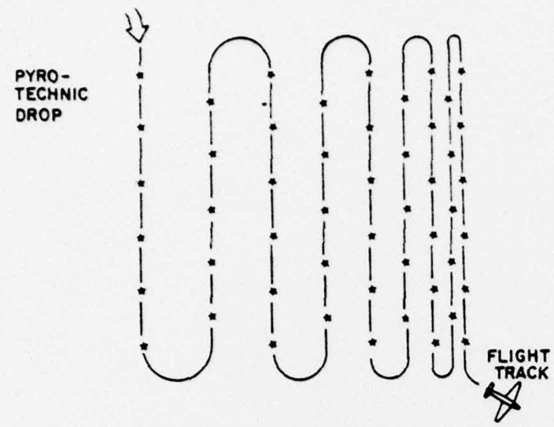

Figure 3. Schematic of raster seeding pattern. Lines are typically 2 n. mi. long,; distances between lines range from 0.5 to 1.5 n. mi.

3. RESULTS

A total of sixteen tests (eleven line, five raster) were performed. On two occasions line tests failed to produce a clearing. The minimum temperatures for the unsuccessful tests were -6°C and -4°C, and the seeding rates varied from 20 to 200 gm/n. mi./ 1000 ft. From Figure 2, this implies a maximum nuclei count of roughly 1×10^{13}/n. mi./ 1000 ft. By contrast, the lowest maximum number of nuclei generated (lowest temperature, highest seeding rate) for the successful tests was approximately 6×10^{13}/n mi/1000 ft.

The highlights of the fourteen successful tests are summarized in Table 1 below.

Table 1

Maximum Cloud Depth:	5900 ft
Maximum Temperature:	-3.0°C
Maximum Average Temperature:	-5.8°C
Lowest Maximum # Nuclei Generated:	6×10^{13}
Maximum Size of Clearing:	37 n mi^2
Attempts to Target Clearing:	5
Successful Attempts:	3

Cloud depths ranged from 1000 to 5900 feet, with an average depth of about 2500 feet. To our knowledge, there have been no successful attempts previously to disperse stratus decks as thick as those reported here.

An important result of this field program was the demonstration that positioning a clearing does not appear to pose any serious difficulty. One of the unsuccessful attempts to do so apparently failed because of an erroneous estimate of the wind direction. The other unsuccessful raster test was positioned correctly, but, because of an underestimation of the wind speed, the clearing did not occur until the affected area had passed over the desired location.

In nearly all cases, visibility was best at the edges of the opening. The center of the annulus-type clearing contained suspended ice crystals. This hampered visibility at low viewing angles. In many instances, the ground was visible only when viewed at a steep elevation angle.

4. FUTURE PLANS

An additional series of field tests is planned for February 1978. At that time, measurements of cloud physics parameters such as particle size distribution will be made both before and after seeding, and the results correlated with visual observations at different viewing angles. The requirement of targeting the clearing will be dropped. Instead, efforts will be directed toward determining the optimum seeding rate as a function of temperature and liquid water content, using the chlorine doped silver iodide flares.

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